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THE LINK BETWEEN MONETARY AGGREGATES AND PRICES

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Perhaps the most critical, and recently the most suspect, economic linkage for monetary aggregates is that between money and prices. Benjamin Friedman argues (1988) that "the quantitative relationships connecting income and price movements to the growth of the familiar monetary aggregates...utterly fell apart" during the 1980s ("mid-1982 to mid-1987"). Thus, he claims, "The presumption that 'inflation is always and everywhere a monetary phenomenon' became progressively less compelling as a substantive rather than tautological description." Even many within the wider circle of analysts who continue to regard inflation as a monetary phenomenon have concluded that the money stock measure M1 and prices are no longer closely, or even systematically, related because of the distorting influence of financial innovations or other factors. Those who allege that financial innovations caused this breakdown point out that the link between M2 and prices should not have been affected by innovations; consequently they have begun to emphasize the M2-price link.[1/]

This paper examines the P-star model of the link between M2 and prices recently developed by Hallman, Porter and Small (1989, 1990) (HPS). It also develops an M1-based variant of the P-star model. The analysis points out and corrects, for the most part, several major shortcomings in the P-star approach. When these corrections are made, the P-star model shows no statistically significant linkage between M2 and prices; there is, however, a significant link between M1 and prices in the M1-based version of the P-star model. Since the P-star model provides an alternative for the direct link between money and prices that was previously estimated in a reduced form model, reduced form equations using M1 and M2 are also examined. These reduced-form estimates contain some of the same statistical problems as the P-star equations. When corrected for these problems, the reduced-form estimates show the same strongly significant relation between M1 and prices and the same statistically insignificant link between M2 and prices.[2/]

HAS THE LINK BETWEEN MONEY AND PRICES BEEN BROKEN?

Figure 1a shows the compound annual rate of increase of the GNP deflator, measured over the most recent two quarters in order to smooth the series, and the trend of money stock (M1) growth, measured by the

20-quarter growth rate. The trend growth rate over the past five years can be interpreted as a summary measure of the monetary determinant of inflation; while prices adjust slowly to changes in the growth of aggregate demand, ultimately, inflation is determined by monetary growth.[3/]

Prior to 1981, inflation follows the trend growth of M1 quite well, except during periods of price control (1971-73) and decontrol (1973-75) and of major changes in the relative price of energy in 1973-75 and 1979-81. After 1981, however, a major gap opens between the two series which is not accounted for by these non-monetary explanations. Figure 1b shows the trend growth of M2 and inflation from 1957 to the present. A similar gap opens after 1981, but in this case it is similar to the gap between the two series from 1957 to 1969.

The principal explanation for the deviation between inflation and the M1 trend after 1981 is the shift in M1 velocity behavior. Rasche (1987) and Tatom (1988a) have pointed to a significant shift in the drift or trend of M1 velocity since about 1981 that is unrelated to the economic factors usually used to explain velocity movements.[4/] This shift apparently reduced both aggregate demand and the aggregate supply price for a given level of real output; consequently, there were no transitory real effects associated with this change.[5] Thus, the average gap between the trend growth of M1 and inflation reflects the decline in the trend growth of M1 velocity, according to this explanation. Whatever the reason for the shift, however, its occurrence has brought into question any presumption that there is a link between M1 growth and inflation that can be exploited by monetary policymakers.

THE P-STAR MODEL OF INFLATION

In the reduced-form approach to the estimation of the direct link between monetary aggregates and prices, inflation depends on long distributed lags of past growth rates of money and on other factors like supply shocks or price controls.[6] In contrast, the HPS P-star model relies on the link between the level of the money stock in the previous quarter and the equilibrium price level associated with it, P-star, in determining inflation. Their model is referred to as the HPS model here to avoid confusion with the M1-based P-star model presented below.

The P-star model is based on two basic concepts: (1) a long-run view of the equation of exchange, and (2) the lagged adjustment of prices to their long-run or equilibrium level. The equation of exchange indicates that the level of prices, P, equals the product of money (M) per unit of output (y), or (M/y), and the velocity of money (V). In the long run, output is presumed to be equal to the economy's potential output, y*. Furthermore, over long periods of time, velocity is presumed to be well described by its mean and its trend; in particular, V is independent of the money stock, M, or potential real GNP, y*. The HPS model uses M2 as the money stock measure. Its velocity, HPS argue, is trendless, so that long-run velocity, V*, is simply its mean $\overline{V2}$. Thus, the long-run price level, P*, equals $(M2/y^*)\overline{V2}$.

Actual prices in any quarter t are assumed to adjust toward their long-run level, P*, at a fixed rate of adjustment, α. Inflation also depends on its own past values in the HPS model, but the sum of past inflation effects equals one, according to HPS, so that the dependent variable can be written as the acceleration of the inflation rate, $\Delta\dot{P}_t$.[7/] The dynamics of inflation are described by:

$$(1) \quad \Delta\dot{P}_t = -\alpha(\ln P_{t-1} - \ln P^*_{t-1}) + \sum_{i=1}^{n} \beta_{t-i}\Delta\dot{P}_{t-i} + N_t + \epsilon_t$$

where the inflation rate, $\dot{P}_t$, is the annualized continuous rate of increase of the GNP deflator, and α is positive. If long-run prices exceed actual prices, inflation temporarily accelerates to close this "price gap;" conversely, if actual prices exceed long-run prices, inflation slows, as prices adjust toward P-star. The term N_t represents nonmonetary shocks like price control-decontrol and energy price effects; these are included in the HPS model by using dummy variables.

The measures of nonmonetary variables discussed in Tatom (1981) are used here to control for these factors.[8/] The price control variable D713751 includes price control effects that began in the third quarter of 1971 and persisted until the decontrol in the first quarter of 1973, and decontrol effects which began in the first quarter of 1973 and lasted until the first quarter of 1975; these effects are constrained to sum to zero.[9/] The effect of energy price changes can be estimated directly using the relative price of energy, p^e, the ratio of the quarterly average of the producer prices for fuel, related product and power, deflated by the implicit price index for business sector output. Current and lagged values of the annualized continuous growth rate of the

relative price of energy, $\dot{p}^e_t$, which equals 400

$\Delta\ln(p^{e}{}_{t})$, are used to capture the effect of past energy price changes on the GNP deflator.

An estimate of the HPS model including these nonmonetary shocks for the period I/1955 to IV/1988, is:

$$
\begin{aligned}
(2)\quad \Delta\dot{P}_t = \; & \underset{(0.34)}{0.077} - \underset{(-5.22)}{17.220G2} \underset{(-9.13)}{-0.747\Delta\dot{P}_{t-1}} \\
& \underset{(-5.60)}{-0.533\Delta\dot{P}_{t-2}} \underset{(-4.11)}{-0.381\Delta\dot{P}_{t-3}} \underset{(-1.96)}{-0.145\Delta\dot{P}_{t-4}} \\
& \underset{(-2.38)}{-1.166D713751_t} + \underset{(2.46)}{0.022\dot{p}^{e}{}_{t-2}}
\end{aligned}
$$

$\overline{R}^2 = 0.40$ S.E. = 1.512 D.W. = 1.95

The term G2 is the price gap on the right-hand side of equation 1, constructed using M2. Except for the difference in the nonmonetary effects, these results are nearly the same as those reported by HPS for the I/1955 to I/1988 period.[10/] The price control variable and the second lag on the change in the relative price of energy are both significant. The use of these two variables results in a better fit than using the HPS oil price and price control dummy variables.[11/]

Figure 2 shows the inflation rate (measured over four-quarter intervals), and gap in the natural logarithms of the actual price level and the equilibrium price level, P-star, measured using M2;

this gap, labeled Gap2, is G2 in equation 2. When P-star exceeds P, the gap is negative; during these periods, e.g., 1963-69, 1971-74 and 1977-78, inflation rose, which is consistent with the hypothesis. As P-star fell relative to P and the gap was either eliminated (1970) or reversed (1974-76 and 1979-85), inflation slowed somewhat. Since early 1985, P-star has risen above actual prices, but inflation has not accelerated sharply.[12/]

A P-Star Model Based on M1

The HPS P-star approach can also be used to model the link between M1 and prices. The principal difference in using M1 to measure P-star is that the velocity of M1 is not mean-reverting, i.e., it does not fluctuate about a fixed mean, as HPS claim is true of M2 velocity. Instead, M1 velocity has a positive trend rate of growth from 1955 to 1981 and a negative trend growth rate subsequently. Thus the velocity of M1, V1, can be described as:

$$(3) \quad \ln V1_t = \delta_0 + \delta_1 t + \delta_2 t2 + \epsilon_t$$

where t is a time trend which begins at the beginning of the sample period in I/1955 and continues to the end of the sample and t2 is a trend that is zero until the first quarter of 1981 and then increases by one in each subsequent quarter.[13/] To measure the price gap ($\ln P_{t-1} - \ln P^*_{t-1}$) using M1, P-star is measured as the product of (M1/y*) and V1*, where V1* is the equilibrium trend level (the fitted value from equation 3). To implement this model, the price gap term in equation 1, $-\alpha(\ln P_{t-1} - \ln P^*_{t-1})$, is broken in to two parts: one, called G1, which is $-\alpha[\ln P_{t-1} - \ln(M1_{t-1}/y^*_{t-1})]$, and the remainder, the term $\alpha \ln V1^*_{t-1}$, is replaced with $\alpha[\delta_0 + \delta_1 t_{t-1} + \delta_2 t2_{t-1}]$.

The comparable estimate for the P-star model using M1 for I/1955 to IV/1988, the same period as in equation 2, is:

$$(4)\quad \Delta\dot{P}_t = \underset{(4.54)}{17.800} - \underset{(-8.89)}{0.755}\Delta\dot{P}_{t-1} - \underset{(-5.52)}{0.549}\Delta\dot{P}_{t-2}$$

$$- \underset{(-4.05)}{0.394}\Delta\dot{P}_{t-3} - \underset{(-2.05)}{0.159}\Delta\dot{P}_{t-4} - \underset{(-4.49)}{15.859}G1_{t-1}$$

$$+ \underset{(4.29)}{0.123}(t_{t-1}) - \underset{(-3.59)}{0.165}(t2_{t-1})$$

$$- \underset{(-2.86)}{1.397}D713751_t - \underset{(-2.17)}{0.022}\Delta\dot{p}^e_{t-1}$$

$\bar{R}^2 = 0.37$ S.E. = 1.554 D.W. = 1.87

The gap measure based on M1 is also significant. Both velocity trend terms and the constant are significant.

The energy price and price control variable are also significant in the M1 variant of the P-star model, but there is a different pattern of significant energy price effects. Two lagged values of the growth of the relative price of energy are included, with their sum constrained to zero. The F-statistic for this constraint is $F_{1,125}$=0.10, which is not significant. A rise in energy prices has no permanent effect on M1 velocity, but initially it falls, and then rises back to its trend level, according to the effect in equation 4.[14]

The expression for the equilibrium velocity of M1 can be derived from equation 4 by dividing the constant and trend term coefficients by the absolute value of the estimated gap (G1) coefficient. The expression for the equilibrium level of ln V1 is (1.1224 + 0.0078t - 0.0104t2).[15] This implies an annual trend, measured at a continuous rate, of 3.11 percent until 1981 and a subsequent trend of -1.04 percent. This estimate of the decline in equilibrium M1 velocity growth is in line with other estimates.[16]

Figure 3 shows the gap, Gap1, between the logarithms of the actual price level and of the M1-based estimate of P^* from equation 4. Gap1 equals G1 plus the implicit fitted value of the logarithm of V1 in equation 4. There are several important differences from the pattern shown in figure 2.

First, in figure 3 the positive gap in 1980-86, which suggests declining inflation, is generally larger in magnitude during the 1983-85 period when a positive gap for the M2 measure also suggests declining inflation (figure 2); its timing also fits the decline in inflation much better than the disinflation gap in figure 2, since the M2-based gap begins to rise much too early in 1977 and is positive from 1979 to the end of 1984. That is, it begins far too early to account for a subsequent decline in inflation; instead, it begins to rise just ahead of the rather significant rise in inflation in 1979-80. Second, while an acceleration in inflation in 1987-88 is suggested by the gap in figure 3, the gap reverses sign in 1988; the comparable gap in figure 2, opened up earlier (in 1985) and is not yet closed. At least in the 1980s, the movements in the price gap for the M1-based measure of equilibrium prices seems to fit actual inflation movements better than does the M2-based measure.

The Dynamics of The Money-Price Link in the P-star Model

The HPS model embeds the price gap, G2, in a pure time series equation--an AR4 model for differences in inflation. This time series model has a standard error of estimate equal to 1.694 for the same period. However, an MA1 model for changes in inflation is often used as the best time series model of inflation, at least for the GNP deflator; this model has a standard error of estimate of 1.6758 for the same period.[17/] Most of the explanatory power in the HPS model arises from its time series components; the choice of specification for this part of the model is critical for the statistical significance and properties of the HPS results. This specification also give rise to peculiar dynamics in the adjustment of inflation to a permanent change in money growth.

The HPS P-star model exhibits a questionable time pattern for the response of inflation to a change in the rate of money growth. It incorporates "overshooting" of inflation in response to changes in the price gaps, so that a given change in the rate of money growth causes inflation to cycle both upward and downward for a considerable period before it reaches its new equilibrium pace. In contrast, inflation responds more gradually to a change in money stock growth in other models. The unusually long and cyclical adjustment process in P-star model is implausible.

Figure 4 shows this characteristic of the P-star adjustment process. The particular estimates for the adjustment path are based on equation 2, but this choice has no effect on the general pattern. A rise in M2 growth causes inflation to rise nearly point-for-point after some time lag in inflation models in which velocity and natural output growth are unaffected by money growth. Thus, a given percentage point rise in M2 growth will raise the equilibrium inflation rate by the same amount. When the lag is relatively long, like in the reduced-form model in the next section, this increase takes up to 5 years or so to be complete.

In figure 4, a 4 percentage point rise in M2 growth raises the rate of increase of P-star, the equilibrium inflation rate, by 4 percentage points, but actual inflation oscillates, initially rising more than 3 percentage points above and then falling 2.5 percentage points below the indicated higher equilibrium value, then cycling dramatically for decades. Inflation surges up to an initial peak of more than 7 percent in about 6 years, then declines to about 1.5 percent in 12.5 years, before rising again. Equilibrium inflation (the rate of increase in P-star) increases point for point with money growth, but the adjustment to this pace takes a relatively long time to stabilize. Indeed, in figure 4, inflation still exhibits a peak-to-trough variation of inflation of 3.1 to 4.7 percent after nearly 40 years of adjustment. More important, however, the P-star model postulates a dynamic adjustment process that has little foundation in the theoretical literature or precedent in earlier estimates of the effect of money growth on inflation.[18/] This feature of the HPS model arises from the choice of the AR4 specification; this choice is rejected below, however.

STATISTICAL PROBLEMS IN THE P-STAR MODEL

The P-star model estimates in equations 2 and 4 include a constraint that the sum of past inflation rate effects on the current inflation rate is one. However, this constraint is neither explicit nor directly tested by HPS. Also, the use of the other component in the equations, the gap term, is predicated on an "error-correction" process in which the mean error or gap is zero and the gap is stationary.[19/] Again, this is not tested by HPS. If the gap does not have these properties, the estimated results are spurious. Granger and Newbold (1974) show that including a nonstationary regressor in an ordinary-least-squares regression can yield spurious results, so that t-statistics can indicate significant statistical relationships where none exist. The HPS model also assumes that M2 velocity is "mean reverting" or stationary, that is, it has a tendency to fluctuate around a fixed mean. The constraint on past inflation and the stationarity assumptions for M2 velocity and for the gap terms are not generally valid, according to the estimates below.

The Constraint on Lagged Inflation in the P-star Model

Equations 2 and 4 follow HPS (1989) by constraining the effects of past inflation on the current inflation rate to equal one; that is, the sum of the coefficients on past inflation rates is constrained to equal one.[20/] If this constraint is relaxed in the M2-based equation 2, the fifth lag on inflation is not statistically significant and so it is dropped in the estimates below. Also, since the time trends for the shift in velocity used in the M1-based estimate in equation 4 are significant when added to the M2-based estimates, they are included in the M2-based estiamte reported in table 1. The sum of the past inflation effects is 0.675 and the t-statistic for testing whether it is significantly different from one is -6.87, which is significantly below the critical value of -3.45 (5 percent significance) for the Dickey-Fuller test on this sum.[21/] Thus, the constraint is rejected.[22/]

The t-statistics for the trend terms are both significant at a 5 percent level in the unconstrained estimate of equation 2. Since the G2 coefficient is -13.5154, the implied annual continuous rate of growth of V2 is 0.5 percent until I/1981, and -2.1 percent subsequently. Thus, it also appears that the assumption that the logarithm V2 is mean-reverting is incorrect; its non-zero trend, like that of the logarithm of V1, shifted in the early 1980s.

Table 1 also provides the best fitting estimate of equation 4 when the constraint on the sum is relaxed. In this case, only the first two lags of inflation are statistically significant. The sum of the five lagged inflation rates implicit in equation 4 is 0.5851. The t-statistic for the difference of this sum from unity is -4.06, which is strongly significant and rejects the hypothesis that the sum is unity. Since the last three lags are insignificant individually and as a group, they are omitted; in the unconstrained form, the sum of the two significant lagged inflation terms is 0.299.[23/] A constraint that the sum of past inflation effects equals one is rejected for both the M2 and M1 versions of the HPS model in table 1.

Stationarity and The P-Star Model

There is a more important statistical reason to question the estimates in equations 2 and 4 and those in table 1. HPS claim that V2 as mean-reverting, or that it fluctuates randomly about a fixed mean, but the results in table 1 suggest otherwise. The Dickey-Fuller test, which formally examines whether M2 velocity has a unit root, cannot reject it; that is, mean-reversion is rejected.[24/]

Schwert (1987) argues that for a series whose difference is generated by an MA1 process, the appropriate test equation for the Dickey-Fuller unit root test, given the number of observations here, is the Dickey-Said specification, which contains 12 lags of the continuous growth rate, ΔlnV2, a constant and the lagged level of lnV2.[25/] In both the HPS sample period and for the period used here, the MA1 parameter for ΔlnV2 is 0.255 (t=-3.02) and the $\chi^2(10) = 13.39$, indicating that the residuals from this process are white noise. Schwert's tabulated critical value (five percent significance level) for the t-statistic on the lagged level of lnV2 in the relevant test equation with 12 lags, when the MA1 coefficient is 0.255, is between 2.82 and 2.85. The test equation for the period II/1955 to I/1988 is:

$$(5)\quad \Delta \ln V2_t = \underset{(2.00)}{0.0439} - \underset{(-2.03)}{0.0082} \ln V2_{t-1} + \sum_{i=1}^{12} \beta_{t-i} \Delta \ln V2_{t-i}$$

$$\bar{R}^2 = 0.13 \qquad S.E. = 0.0109 \qquad D.W. = 2.00$$

The t-statistic is too small in absolute value compared with the critical value, so that the unit root hypothesis cannot be rejected.[26/] Thus, lnV2 is not stationary, or mean-reverting, according to this test.[27/]

The gap measure G2 and the M1-based gap measure constructed using P-star from the M1 model, Gap1, are not stationary either. When the first-difference of Gap1 is regressed on a constant, its lagged level and two, eight, and twelve lagged values of the dependent variable, the t-statistic for the lagged level of the composite is -1.04, -1.05 and -1.02, respectively.[28/] The same test for the gap measure G2 yields t-statistics of -2.65, -2.26, and -1.98, for two, eight and 12 lags, respectively. For both measures, the critical value of the Dickey-Fuller test statistic is -2.89 and the critical statistic value for the test proposed by Schwert (1987) is about -2.82.[29/] The unit root test does not reject the presence of a unit root for G2 or Gap 1 using either specification for the test.

Inflation itself is not a stationary process. When the change in inflation ($\Delta\dot{P}_t$) is regressed on its lagged level ($\dot{P}_{t-1}$), the first four of its own past values and a constant, the t-statistic on the lagged inflation rate is -1.79, which is not statistically significant.[30/] More lags on the dependent variable are unnecessary to show that inflation has a unit root.

Since the gap measures are nonstationary, the estimates in equations 2, 4 and in table 1 are spurious. One way around this problem is to first-difference the estimates in table 1. The first-differences of $\dot{P}_t$ G1, G2, t2, D713751 and $\dot{p}^e$ are stationary.[31/] The first two columns of table 2 show the results from differencing the variables used in equations 2 and 4, after dropping the statistically insignificant terms.

The resulting estimates look like those in equations 2 and 4 because lagged values of $\Delta\dot{P}$ appear on the right-hand-side; however, the other variables (including the gap measures) are now differenced as well. The coefficient estimates, however, are theoretically identical to their counterparts in table 1, and, except for the lagged dependent variables, in equations 2 and 4 also. The G2 and G1 measures remain significant in the first two columns. The length of the lag for the lagged dependent variables in the G2 specification shortens to only one in the differenced version and the trend (measured by the constant) and its shift ($\Delta t2$) are not significant in this form; otherwise, the results in table 1 hold up for both the G2 and G1 specifications.

Since the best time series model for changes in inflation is an MA1 model, the first-difference form of the equations in table 1 were also estimated with an MA1 correction error process. The most significant results containing G2 or G1 are given in the last two columns of table 2. No lagged dependent variables are significant when the significant MA1 correction is included; the trend shift is significant in both equations, however. The energy price specification for the G1 equation also changes to include accelerations in the growth rate of energy prices two quarters earlier rather than its first-difference.

The most important change in table 2 is that the price gap term measured using M2 is not statistically significantly different from zero.

Assessing the significance of the ΔG coefficient is hampered by the fact that it is the constrained estimate of the effect of past inflation ($\dot{P}_{t-1}$) and of the effect of the past growth of P-star ($\dot{P}^*_{t-1}$) on the current acceleration in inflation ($\Delta\dot{P}_t$). The appropriate test statistic for the former is a Dickey-Fuller statistic that has a critical value (5 percent significance level) of -3.45, while the appropriate test statistic for the latter is a standard t-statistic, which has a critical value (5 percent significance level, one-tail test) of -1.65. When the $\Delta G2$ term in the equation in the third column in table 2 is separated into these two components, the t-statistic for lagged price growth is -1.74, and that for lagged P-star growth is 1.62; the absolute value of each statistic is below that of critical value, so neither effect is statistically significant. When the insignificant $\dot{P}_{t-1}$ variable is dropped from the estimate, the t-statistic for M2-based $\dot{P}^*_{t-1}$ measure falls to 0.80. Neither component of $\Delta G2$ is statistically significant, so the P-star measure based on M2 is uninformative for inflation.[32]

The gap measure constructed using M1 remains significant in the last column in table 2, despite the inclusion of the MA1 process. Moreover, both its components are statistically significant, unlike those in the M2-based estimate. The t-statistic for the lagged M1-based P-star growth rate is 9.13 and that for the lagged rate of price increase is -7.66, nearly twice the size of the critical value. Hence, it appears that the significance of the gap measure in the HPS model using M2 arises from the omission of the significant MA1 process.[33/] The P-star model that uses M1 continues to exhibit a significant price gap (G1) term, however, even in this case.[34/]

THE REDUCED-FORM MODEL

Estimates of typical reduced-form equations for the continuous annual rate of increase of the GNP deflator, $\dot{P}_t$, using M1 and M2 are presented in the first two columns of table 3. The period used is I/1955 to IV/1988, the same as for the P-star estimates. The reduced-form equations include 19 lags for M2 growth or 20 lags for M1 growth, along with the 1971-75 price control and decontrol variable above, four lagged values of the growth rate of the relative price of energy, an intercept shift in the third quarter of 1982 and, for M2, a constant.[35/] The M2 equation also includes correction for significant first-order autocorrelation. The money growth coefficients are estimated to lie along a third degree polynomial in each case.[36/] The standard error of the M2 equation is 1.577 and the adjusted $\overline{R}^2$ is 0.67; for M1 the comparable statistics are 1.400 and 0.93, respectively. The sums of the money coefficients are not significantly different from one. Both equations show a significant shift in the intercept after mid-1982.

When the money growth rate coefficients in table 3 are constrained to equality, the constraint cannot be rejected when compared to the equations using the polynomial distributed lags. Such estimates are also reported in table 3. The F-statistic for this constraint on the first M1 equation in table 3 is $F_{2,127}=3.03$ which is marginally lower than the critical value (5 percent significance) of 3.07; for the M2 equation, the test statistic is $F_{2,125}=1.03$ which is substantially lower. Thus, the constraint that the quarterly money growth coefficients are equal is rejected in either case. Constraining the coefficients in this way implies that the effect of money growth on inflation is assessed using a trend measure like those in figure 1a and 1b.

The growth rates of M1 and M2 used in table 3 are also not stationary. When the first-difference of M1 growth ($\Delta\dot{M1}_t$) is regressed on lagged M1 growth ($\dot{M1}_{t-1}$), four lagged values of itself and a constant for the period I/1955 to IV/1988, the t-statistic for lagged M1 growth is -2.63, which is smaller in absolute value than the critical value (5 percent significance) for stationarity of -2.89. For M2, the more powerful test involving 12 lags of the dependent variable yields a test statistic of -2.16, which is below the same critical value of -2.89.[37/] Thus, M1 and M2 growth are nonstationary, or have unit roots. The potential spurious regression bias is eliminated by differencing the estimates, just as was done in table 2 for the P-star estimates. None of the first differences of the variables used in table 3 have unit roots; they are all stationary.

Table 4 presents estimates of the reduced-form model shown on the right in table 2, but all of the variables have been made stationary by first-differencing. A significant MA1 correction is included. The central features of the table 2 equations are not altered by these changes, except for M2. In particular, the link between money and prices remains significant for the M1 measure, but not for M2; the sum coefficient for past M1 growth is not significantly different from one but that for M2 is well below one and not significantly different from zero. The shift in the trend of velocity is significant for both the M1 and the M2 measure. Like the P-star results, the link between money and prices is not significant when M2 is used and when the linkage is estimated using stationary variables and with correction for a significant MA1 process. Even under these conditions, however, there is a significant link between money and prices when the M1 measure is used. Each percentage point increase in M1 growth results in an equal increase in inflation in the long run.[38/]

Thus, only the M1-based estimates strongly support the hypothesis of a significant link between money and prices. The difference in the dynamics of adjustment is slight; in the P-star equation a permanent rise in M1 growth takes longer to reflect the point-for-point rise in inflation. In particular, after 5 years the rise in inflation is only three-fourths complete, unlike in the reduced-form equation in table 4 where the adjustment is complete. The process of adjustment is continuous and does not involve overshooting or oscillations in either case, however.

The Davidson-McKinnon J-test, which adds fitted values from each model to the other, is not strongly conclusive in choosing between the two M1-based models. When the fitted value from the M1-based reduced form model in table 4 is added to the M1-based P-star model in table 2, its t-statistic is 2.53, which is statistically significant at the 5 percent level where the large-sample critical value is 1.96. Similarly, when the fitted value from the P-star model in table 2 is added to the reduced-form model in table 4, its t-statistic is 1.94, which is marginally insignificant. At this margin, the J-test rejects the P-star model using M1 in favor of the M1-based reduced form model.[39/]

CONCLUSIONS

Considerable doubt has arisen in the past decade about the existence of a link between money and prices. More recently, Hallman, Porter and Small have developed a model of inflation that directly links inflation to the growth of M2. This article discusses the advantages and shortcomings of the HPS P-star approach and compares it to reduced-form estimates using both M1 and M2. The results indicate that there was a significant velocity shift for M1 and M2 in the 1980s, using either approach.

The P-star equations were found to be subject to a spurious regression bias because the principal variable, the price gap, is nonstationary. A P-star model constructed using M1 fits the data better than the HPS model based on M2, but it also suffers from the same spurious regression problem as the M2-based model. The results also show that critical HPS assumptions--the mean-reverting behavior of V2 and, more importantly, of the disequilibrium price gaps, are rejected for the P* models. The dynamics of inflation in these models also was found to exhibit implausible oscillations and an extremely long adjustment period.

When the stationarity problems are corrected and the appropriate time series specification for inflation is used, the price gap measure developed by HPS for M2 is found to be statistically insignificant, while that developed here for M1 is significant. The reduced-form estimates here are subjected to the same adjustments. The M2-based reduced form model yields an insignificant link between M2 and prices in the first-differenced equation with the significant MA1 correction. The M1-based reduced form shows a strongly significant link between money and prices even in this case, however. At the margin, the J-test rejects the M1-based P-star model in a comparison of the P-star and M1-based reduced-form model.

The HPS P-star model and its estimation raise econometric issues that are seldom explored in inflation modeling. When these issues are addressed, however, the HPS model using M2 is rejected. The results presented that use M1, however, suggest that there is a strong, continuing and exploitable link between M1 and prices. A significant break in the trend of velocity is found here for both M1 and M2 using both types of models. Nevertheless, there is a continuing one-to-one relationship between increases in trend M1 growth and increases in inflation.

FOOTNOTES

1/ See, especially, Cox and Rosenblum (1989) Friedman (1988), Haslag (1990) and Mehra (1988) for recent examples of this argument.

2/ The effects of financial innovations on the use, composition and demand for M1 and M2 have recently been examined in Tatom (1990).

3/ In a rational expectations framework, inflation is determined by the expected rate of money growth. According to Barro (1978), this expected monetary growth rate depends on a weighted average of unanticipated (or, more simply, past) money growth over a period nearly the same as the 20-quarter trend of M1 growth used here.

4/ Rasche (1987) argues that this shift is correlated with a shift in the drift of interest rates and that both shifts may be associated with a decline in inflationary expectations. Nevertheless, no evidence that this shift in the drift of money demand is related to measurable economic factors, even those measured indirectly or by proxy, has been found.

5/ See Tatom (1988b). The argument is that the shift in aggregate demand, given the money stock, must be matched by an equal shift in aggregate supply to avoid real effects or an output and employment change. If wages and other costs adjusted down proportionately with the unknown factor shifting aggregate demand, then real effects would be avoided. For example, if a decline in expected inflation boosts agents' money demand and simultaneously lowers their expected wages and other factor costs proportionately, then prices and velocity fall proportionately for a given money stock and its expected growth rate, without generating transitory real economic effects. The evidence in Tatom (1988b) shows that "unanticipated" GNP movements in the 1980s, including those associated with the shift in the drift of M1 velocity have not had a significant effect on the unemployment rate.

6/ See Stockton and Glassman (1987), or Mehra (1988) for a comparison of models like this to other inflation models. Mehra (1988) is one of the few studies to estimate such an equation using M2, but he uses much shorter lags for both M1 and M2 than those contained in the estimates of the reduced-form model below.

7/ If $\dot{P}_t$ is a function of Z plus the vector $\beta_1 \dot{P}_{t-1}+\beta_2 \dot{P}_{t-2}+\beta_3 \dot{P}_{t-3}+\beta_4 \dot{P}_{t-4}+\beta_5 \dot{P}_{t-5}$ but $\beta_1+\beta_2+\beta_3+\beta_4+\beta_5$ equals one, then $\dot{P}_t$ can be written as

$Z+\dot{P}_{t-1}-(\beta_2+\beta_3+\beta_4+\beta_5)\ \Delta\dot{P}_{t-1}-(\beta_3+\beta_4+\beta_5)\ \Delta\dot{P}_{t-2} - (\beta_4+\beta_5)$ $\Delta\dot{P}_{t-3}-(\beta_5)\ \Delta\dot{P}_{t-4}$. Subtracting $\dot{P}_{t-1}$ from both sides of the equation yields equation 1, where Z is the first term on the right, the price gap.

8/In the HPS model, both price controls and energy price shocks are handled with dummy variables. The price control variable (PC1PC2, here) is a dummy variable that equals one in III/1971 to IV/1972 and minus one from I/1973 to IV/1974; otherwise this variable equals zero. HPS claim that only the 1973-74 energy price rise has a significant effect on inflation; they control for it using a dummy variable that equals one in IV/1973, minus 1 in I/1974, and zero otherwise. It is called DOS1.

9/ The price control-decontrol dummy variable used here has a value of one in III/1971 to IV/1972, two-ninths in the first quarter of 1973, minus seven-ninths in each quarter from II/1973 to I/1975, and zero otherwise. This pattern imposes a constant average reduction in measured inflation in III/1971 to I/1973, and a constant average rise in measured inflation in I/1973 to I/1975 that exactly offsets the earlier effect. The constraint that the level of prices was unaffected by controls after the first quarter of 1975 cannot be rejected at conventional statistical significance levels.

10/ HPS omit the intercept because it is insignificant. HPS also use a sample period of I/1955 to I/1988, but they report y^* data to the end of 1988. The estimates here end in IV/1988 because they use the HPS measure of y^*.

11/ When the HPS variables, PC1PC2 and DOS1, are used in equation 2 in place of the nonmonetary variables, the standard error of the estimate is higher for each substitution or both. When PC1PC2 is added to the equation, it is not significant (t=-0.33). When DOS1 is added to the equation, it has a significant coefficient of 2.284 (t=2.15), but there is little change in the energy price coefficient, 0.024 (t=2.56), or other coefficients; the price control variable's coefficient of -1.138 (t=-2.33) is nearly the same in this case, too. While, the standard error of the estimate drops to 1.498, the inclusion of DOS1 is excluded because its effect is orthogonal to the energy price and price control variables and its inclusion is otherwise unmotivated.

12/ HPS (1989) note this too; they test whether the absence or delay of this acceleration arose from financial innovations, especially the introduction of Super Now accounts and money market deposit accounts (MMDA), which could have boosted the demand for M2 and lowered its long-run velocity. Using a dummy variable which equals one after III/1982 and zero earlier to test for such an effect, they find the effect to be statistically insignificant.

13/ Equation 4 is used to specify the structure for V1 in the M1-based P-star equation. When equation 4 is estimated independently however, it includes a significant second-order autocorrelation correction. This second-order autoregressive error structure is insignificant when included in the estimation of equation 4, below, and its inclusion has no effects on the other estimates in the equation. Therefore, it is omitted in the various estimates below that use M1.

14/ The permanent effect of a supply shock on prices arises from a change in y^*. The y^* series used here and in the HPS model shows a significant negative effect of a rise in energy prices on y^*. In particular, the growth rate of y^* falls from about 3.4 percent in 1966-73 to 2.8 percent in 1974-79 and to 2.5 percent in 1980-88. In addition, however, M1 velocity is significantly depressed temporarily by a rise in energy prices; see Tatom (1981). In the P-star framework, such a velocity effect on P-star will show up as a transitory negative effect of energy prices on the inflation acceleration like that observed here. The effects of energy price increases on inflation are generally positive in the estimates below, however, which suggests that the y^* effect is generally biased downward in magnitude so that part of the effect of an energy price rise (fall) shows up as a permanent rise (fall) in equilibrium velocity.

15/ A regression of lnV1 on a constant, t and t2 for the same period results in the nearly identical expression: (1.1050+0.0079t-0.0114t2) where the t-statistics are 73.40, 34.38 and -11.11, respectively. This equation has an adjusted R-squared of 0.998, a standard error of 0.0107 and a Durbin-Watson statistic of 1.90; the estimate includes a correction for second-order autocorrelation where ρ_1=1.114 (t=13.13) and ρ_2=-0.237 (t=-2.79). Without the autocorrelation correction, the lnV1 expression is nearly the same (1.1088+0.0080-0.0115) and the t-statistics are, of course, much larger; the Durbin-Watson statistic is 0.19, however.

The residuals from the OLS estimate are mean-reverting, so that lnV1 is trend stationary. When the first-difference of the OLS residuals are regressed on the lagged level of the residual and four lagged dependent variables, the t-statistic on the lagged level of the residual is -3.22, which equals the critical value for such a test, according to Perron (1989), and so does not reject trend stationarity. When the only significant first-lagged value of the dependent variable is used instead of four lagged dependent variables, this t-statistic is -3.23 which slightly exceeds the critical value providing further support for the conclusion.

16/ For example, the decline in the inflation rate, given money (M1) growth, found in Tatom (1988a) is 4.5 percentage points, not much different from the 4.15 percentage point decline here. On the other hand, a direct estimate of the decline in the M1 velocity trend growth is from a 2.6 percent rate to a 3.3 percent rate of decline, a fall of 5.9 percentage points. An estimate of the M1 velocity trend-rate decline using the approach taken by Rasche (1987) shows a decline of 2.35 percentage points in the drift of M1 velocity for the sample period I/1953 to IV/1985. See Tatom (1990).

17/ For example, this model is used by Rasche (1989). The MA1 model has a Box-Pierce Q-statistic for twelve lags of 5.56; the hypothesis that the errors are white noise cannot be rejected. The errors from the AR4 model are also white noise, however. The principal difference is the slightly superior fit and the relatively smaller number of right-hand side variables, or variables larger number of degrees of freedom, of the MA1 model. Rasche (1989) points out the near equivalence of an AR4 and MA1 model where the former has geometrically declining coefficients like those in the HPS model.

18/ Humphrey (1989) points out that earlier statistical analyses had been based on movements in the price level relative to an equilibrium price and that "overshooting" is a characteristic of some theoretical models, so that there are precedents to some aspects of the P-star model, but he provides no evidence that such long and oscillating responses of inflation to a change in money growth were anticipated in any earlier work. Gordon (1987, pp. 252-63) shows that a relatively mild degree of overshooting can occur for a relatively short time if inflationary expectations are adaptive.

19/ Stationarity means a variable tends to revert to its mean or to its deterministic trend; it does not drift relative to its trend. The formal definition is if X_t has a finite autoregressive representation, $X_t = \sum_{i=1}^{n} \beta_{t-i} X_{t-i} + \epsilon_t$, and the roots of its characteristic equation lie outside the unit circle, then X is defined as a stationary process.

20/ Kuttner (1989, 1990) also has criticized this constraint. He argues that its inclusion leads to the overshooting and oscillating properties of inflation that are discussed below. Kuttner removes overshooting by altering the model to use the change in the past gap, rather than its level, and he adds two past levels of the gap between actual and potential real GNP. These output gaps are not significant when added to equations 2, 4 or table 1. The second lag of the price gap also is not statistically significant when added alone to these estimates. All three variables are insignificant individually, and as a group.

21/ Fuller, Hasza and Goebel (1981) explain that the Dickey-Fuller test for a unit root is the appropriate test for this constraint on lagged dependent variables. When the trend and its shift are not included in first equation in table 1, the constraint on past inflation is not rejected using the Dickey-Fuller test; the value of the t-statistic for testing whether the sum for the significant four lagged inflation effects is -2.11 which is smaller in absolute value than the critical value of -2.89. In this case, the constraint is not rejected. For all five lags implicit in equation 2, the relevant t-statistic is -2.27, which also is too small to reject the sum constraint.

22/ When all the variables listed in table 1 are used with either G1 or G2, so that the only difference in the estimates is the use of G1 or G2, the standard error of the M2-based equation is 1.480, well above the 1.393 standard error in the M1-based estimate.

23/ An F-test for the two past inflation rate effects in the M1-specification in table 1 yields an $F_{2,128}$=5.82, which is strongly significant at a 5 percent level.

24/ The power of unit root tests and the importance of their implications are the subject of growing doubt. See Christiano and Eichenbaum (1990) and Diebold and Rudebusch (1990). The latter argue that the power of the conventional unit root test is "likely to be quite low." Unlike Schwert (1987), however, who argues that the conventional test can be biased in favor of stationarity, they argue that the unit root test can be biased against stationarity when a process is fractionally integrated.

25/ When only four lagged values of the dependent variable are used, the t-statistic on $lnV2_{t-1}$ is -2.94 which is significant and indicates stationarity; this test is biased, however. See Schwert (1987).

26/ The β coefficients on the lagged growth rates are not reported because they are unimportant for the purpose at hand and require considerable space.

27/ Rasche (1989) argues that the stationarity of V2 is doubtful. Tatom (1990) argues that M2 is biased by an amount proportional to the share of money market deposits in M2. An adjusted M2 velocity series also has a unit root, however, even when only one lagged growth rate is included. This adjustment computes M2 velocity by adding -0.261 s2, where s2 is the share of money market balances (MMDAs plus MMMFs) in M2, to the logarithm of M2 velocity (or removing that much from the logarithm of M2), following Tatom (1990). The t-statistic is -2.72, in this case, below the critical 2.89 value.

28/ These regressions were estimated over the period II/1958 to IV/1988, because the $V1^*$ and $\overline{V2}$ measure, and, therefore, the P-star and gap data begin in I/1955.

29/ The MA1 coefficient for the change in G2 is 0.52, while those for the change in G1 and Gap1 are 0.47 and 0.05, respectively. These three series are not well described as a MA1 process for their differences, however, since the residuals from these MA1 models are not white-noise.

30/ This unit root result is counter to the rejection of the constraint on the sum of past inflation effects reported above for the table 1 equations. The rejection of the unit root in the table 1 equations must arise from the inclusion of the additional trend gap and energy price change in these equations, or from the spurious regression bias that exists in estimates like these.

31/ The price control-decontrol variable and the growth rate of the relative price of energy are both stationary, as are their differences.

32/ The size and significance of the other variables in these two estimates involving the lagged growth of the M2-based P-star measure are unaffected by these alterations.

33/ The implied M1 velocity growth for this estimate is a continuous annual rate of 4.1 percent from 1955 to I/1981, then it declined to a -4.5 percent rate. These growth rates and the decline are much larger in absolute value than those in footnote 15 above.

[34] Since the lagged dependent variables are not significant and are omitted, inflation does not overshoot or oscillate like in figure 4.

[35] This functional form for M1 is used in Tatom (1988) and it is similar to the monetarist equation used in Stockman and Glassman (1987). They consider variants of this reduced-form equation in a comparison of models of inflation. The closest equation to the one used here includes only 16 lags of M1 growth with coefficients along a fourth degree polynomial, separate price control variables, and a constant for sample periods: IV/1963 to IV/1976 and IV/1963 to IV/1982. In comparisons of forecast errors for intervals of the period 1977 to 1984, they show that after 1982 this equation's mean error and root-mean-squared error, each rose to almost 5 times the in-sample standard error. Such an outcome generally indicates a significant intercept shift, like that captured by the D823 term used here.

The lag length for M2 was chosen by minimizing the standard error for a broad of polynomial degrees for the distributed lags. A third degree polynomial is used for both M1 and M2. This degree cannot be rejected when tested against a second or higher order polynomial for the lag lengths chosen. The intercept shift is dated in II/1982, following Tatom (1988). An earlier shift (II/1981) fits the M1 velocity shift better in an Andersen-Jordan type GNP equation and in the P-star model, but the later shift (II/1982) fits reduced-form price equations better.

[36] The M1 equation includes a tail constraint; its inclusion cannot be rejected and it has no effect on the lag length selection. A tail constraint can be rejected for the M2 equation, however, so it is not included.

[37] When only four lags of the dependent variable ($\Delta\dot{M}2$) are included, the t-statistic on $\dot{M}2_{t-1}$ is -3.19, which is large enough in absolute value to suggest stationarity, but, as Schwert (1987) explains, this test is biased toward rejection of the unit root when the change in the variable ($\Delta\dot{M}2$ in this case) is generated by an MA1 process. The MA1 parameter for $\Delta\dot{M}2$ is -0.20 (t=-2.43). The MA1 parameter for $\Delta\dot{M}1$ is -0.42 (t=-4.94).

[38] Christiano (1990) argues that the forecasting performance of the HPS P-star model compares quite unfavorably with the performance of several other inflation models. He uses an estimate

like equation 2, however, to assess the performance of the HPS model. Since this HPS model is rejected when its statistical flaws are corrected, such a comparison may not be meaningful.

39/ The insignificance of M2 in table 4 and the comparative results for the M1-based reduced-form model, particularly the J-test results, are not affected by the inclusion of the three insignificant lagged energy price effects in the reduced form equations.

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Table 1
P^* Equations Without a Constraint on Past Inflation

Dependent Variable: $\dot{P}_t$

	Using M2	Using M1
constant	0.653	22.066
	(2.14)	(5.94)
$\dot{P}_{t-1}$	0.210	0.149
	(2.58)	(1.89)
$\dot{P}_{t-2}$	0.178	0.150
	(2.16)	(2.03)
$\dot{P}_{t-3}$	0.103	--
	(1.23)	
$\dot{P}_{t-4}$	0.184	--
	(2.31)	
Price Gap	-13.515	-19.005
	(-4.13)	(-5.72)
t_{t-1}	0.016	0.192
	(2.17)	(6.40)
$t2_{t-1}$	-0.072	-0.377
	(-2.02)	(-6.48)
$\dot{p}^e_{t-2}$	0.031	0.030
	(3.96)	(3.20)
D713751	-1.255	-1.458
	(-2.60)	(-3.15)
$\overline{R}^2$	0.73	0.73
S.E.	1.479	1.411
D.W.	1.99	2.01

Table 2
First-Differenced Specifications of the P-Star Models

Dependent Variable: $\Delta\dot{P}_t$			Price gap measure based on:	
	M2	M1	M2	M1
Constant	0.021 (0.15)	0.537 (2.72)	0.054 (1.20	0.275 (6.12)
$\Delta G2$	-42.828 (-2.78)	--	-14.627 (-1.92)	--
$\Delta G1$	--	-49.229 (-3.35)	--	-26.973 (-5.69)
$\Delta\dot{P}_{t-1}$	-0.371 (-5.01)	-0.499 (-6.41)	--	--
$\Delta\dot{P}_{t-2}$		-0.205 (-2.67)	--	--
$\Delta t2_{t-1}$	--	-1.021 (-2.70)	-0.253 (-2.40)	-0.579 (-7.27)
Δ D713751	-2.399 (-2.63)	-2.468 (-2.81)	-1.987 (-3.46)	-1.810 (-3.91)
$\Delta\dot{p}^e_{t-2}$	0.032 (3.03)		0.029 (2.94)	0.028 (3.09)
$\Delta[\Delta\dot{p}^e_{t-1}]$		-0.023 (-3.31)	--	--
MA(1)	--	--	-0.705 (6.40)	-0.882 (17.86)
$\overline{R}^2$	0.30	0.39	0.39	0.47
S.E.	1.627	1.553	1.525	1.425
D.W.	2.18	2.17	1.94	1.83

Table 3
Reduced-Form Equations for the Rate of Increase of Prices
(I/1955 to IV/1988)

Dependent Variable: $\dot{P}_t$	Polynomial Constraint on Money Growth Coefficients		Equality Constraint on Money Growth Coefficients	
	M=M1	M=M2	M=M1	M=M2
constant	--	-3.168	--	-2.932
		(-2.95)		(-2.70)
Price Control/Decontrol	-2.173	-1.332	-2.057	-2.078
	(-4.53)	(-1.67)	(-4.31)	(-3.21)
D823	-5.153	-2.378	-5.323	-1.916
	(-10.81)	(-3.54)	(-11.60)	(-2.71)
$\dot{p}^e_{t-1}$	-0.003	-0.006	-0.006	-0.004
	(-0.28)	(-0.48)	(-0.53)	(-0.29)
$\dot{p}^e_{t-2}$	0.046	0.043	0.045	0.045
	(3.65)	(3.33)	(3.33)	(3.50)
$\dot{p}^e_{t-3}$	-0.010	-0.011	-0.013	-0.009
	(-0.74)	(-0.80)	(-0.94)	(-0.70)
$\dot{p}^e_{t-4}$	0.022	0.016	0.024	0.020
	(1.87)	(1.22)	(2.13)	(1.54)
$\dot{M}_{t-i}$ $(\sum_{i=0}^{n} \omega_i)$	1.098	1.073	1.102	1.034
	(30.49)	(3.08)	(32.79)	(6.99)
n	20	19	20	19
$\hat{\rho}$	--	0.337	--	0.353
		(4.00)		(4.25)
$\bar{R}^2$	0.93	0.66	0.92	0.46
S.E.	1.449	1.602	1.472	1.602
D.W.	1.85	2.07	1.79	2.06

Table 4
First-Difference Estimates of the Reduced-Form Equations

Dependent Variable: $\Delta\dot{P}_t$

	M=M1	M=M2
Constant	-0.006	0.018
	(-0.29)	(0.58)
Δ Price Control/Decontrol	-2.100	-2.201
	(-4.26)	(-4.03)
ΔD823	-3.760	-2.948
	(-4.27)	(-2.75)
$\Delta\dot{p}^{e}_{t-1}$	-0.009	-0.011
	(-0.81)	(-1.00)
$\Delta\dot{p}^{e}_{t-2}$	0.043	0.040
	(3.40)	(3.15)
$\Delta\dot{p}^{e}_{t-3}$	-0.014	-0.015
	(-1.11)	(-1.22)
$\Delta\dot{p}^{e}_{t-4}$	0.021	0.016
	(1.84)	(1.36)
$\Delta\dot{M}_t(\sum_{i=0}^{n} \omega_i)$	0.820	0.369
	(3.39)	(1.27)
n	20	19
MA1	-0.866	-0.778
	(17.75)	(12.99)
$\bar{R}^2$	0.42	0.39
S.E.	1.483	1.520
D.W.	1.87	1.97

Figure 1A

Inflation and Trend Money Growth (M1)

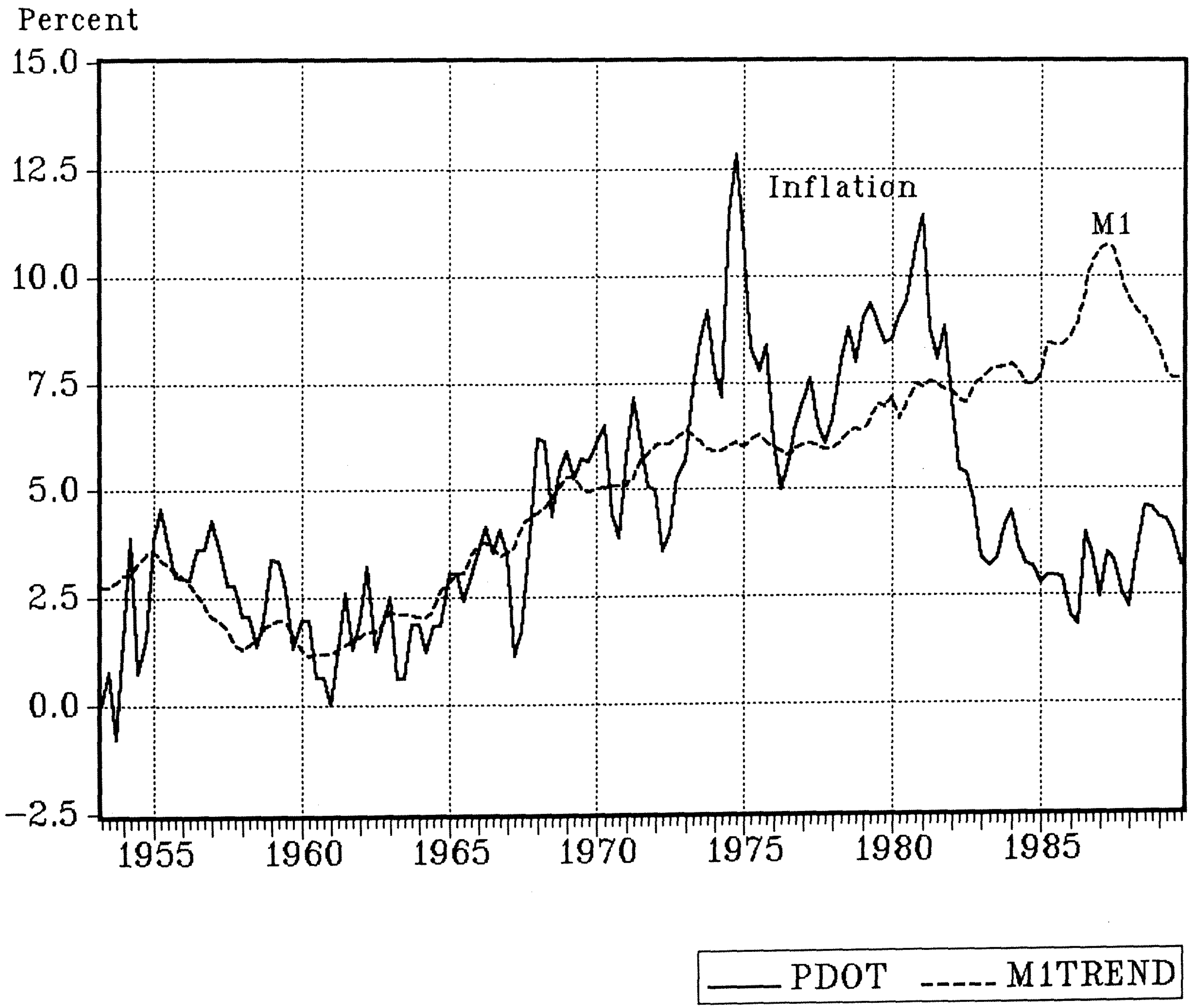


Figure 1B
Inflation and Trend Money Growth (M2)
Percent

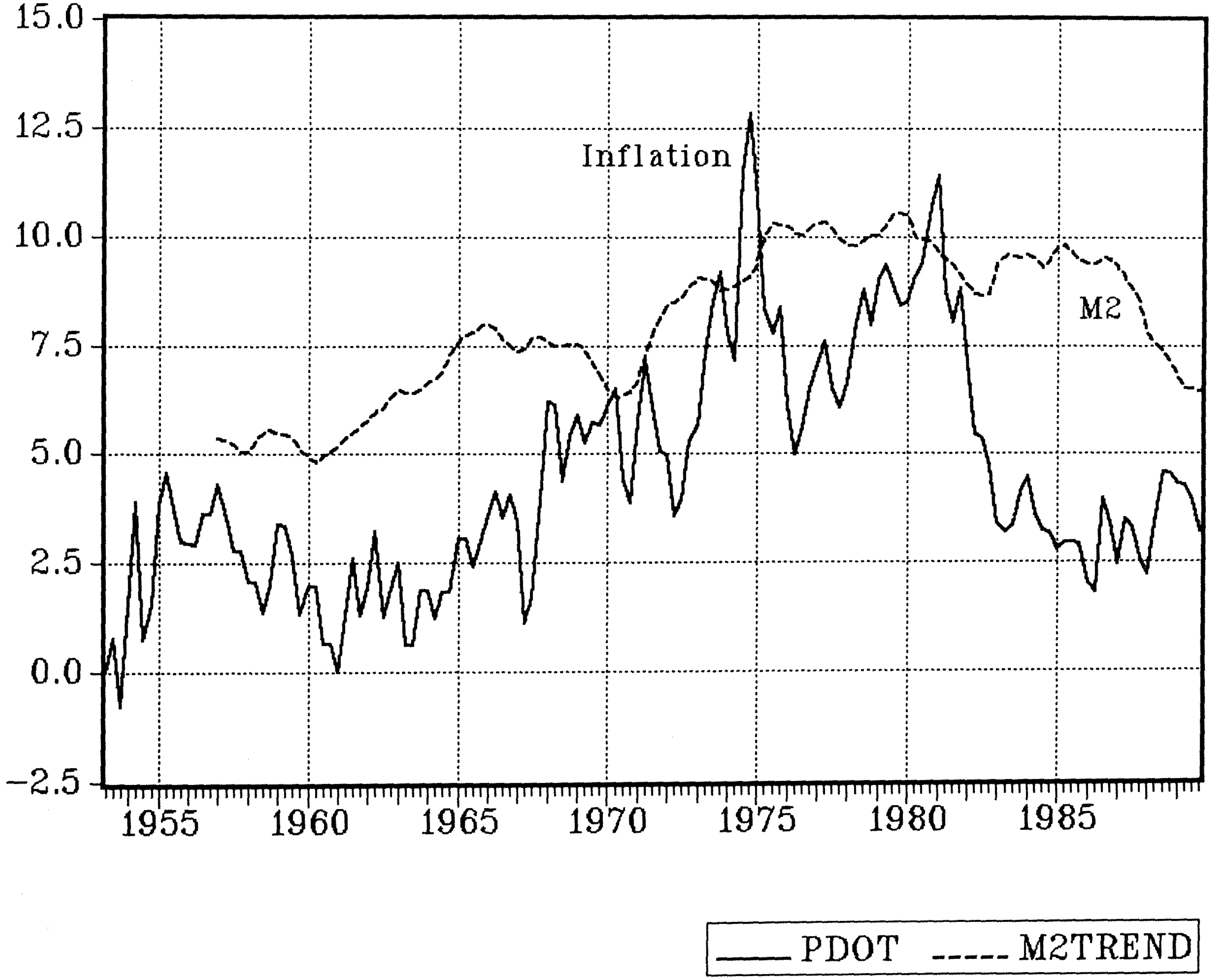
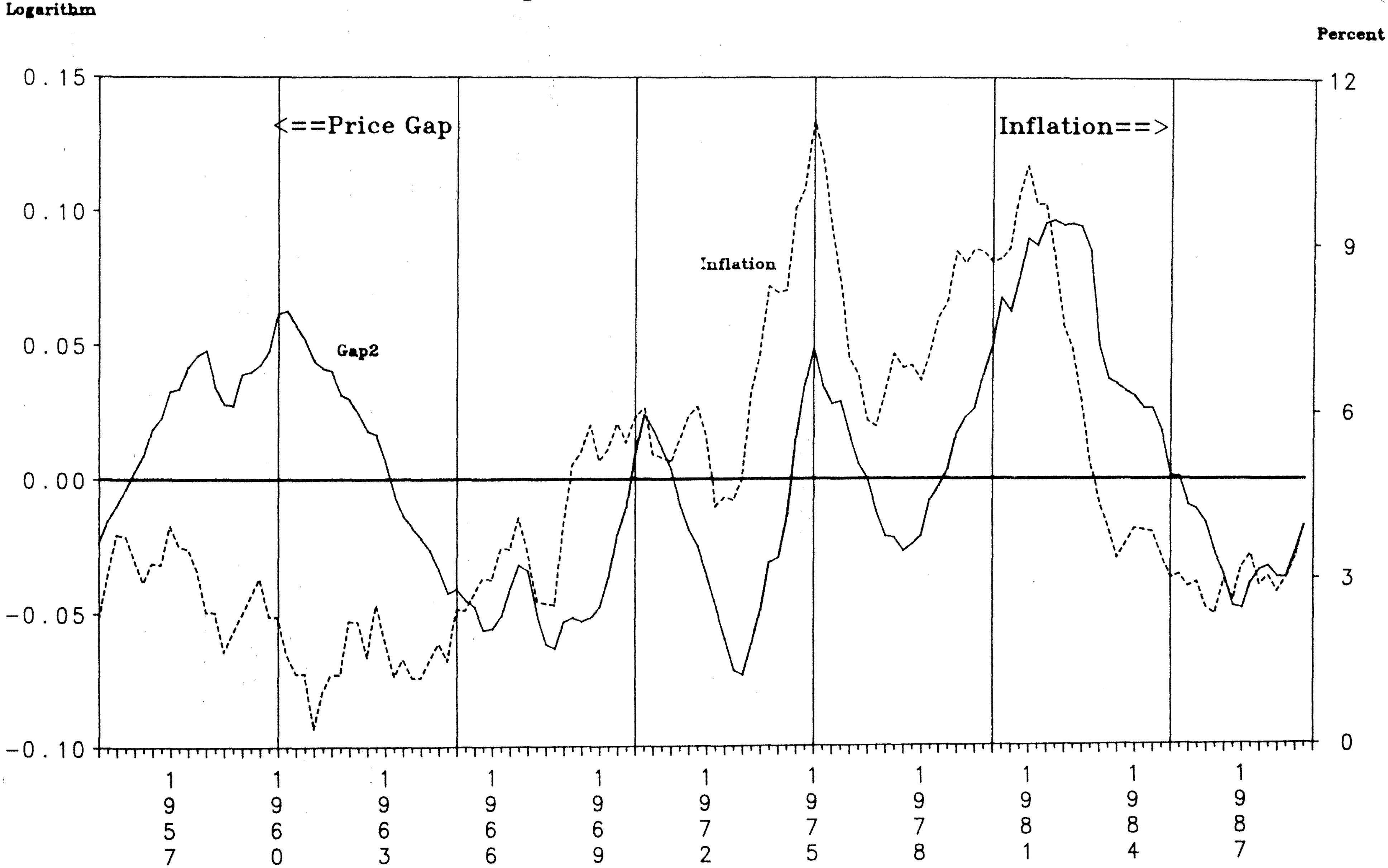
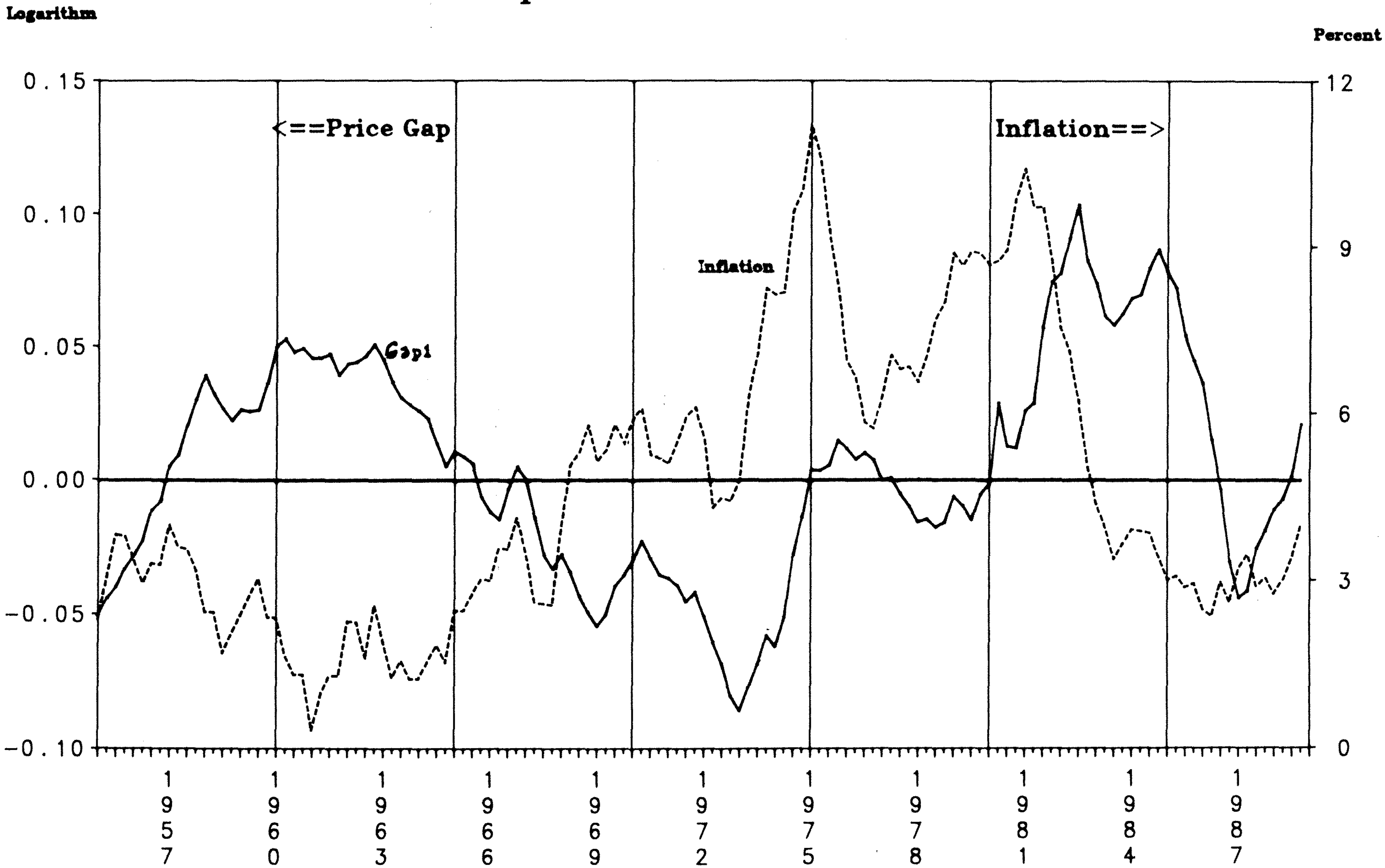


Figure 2
Inflation and the M2 Price Gap



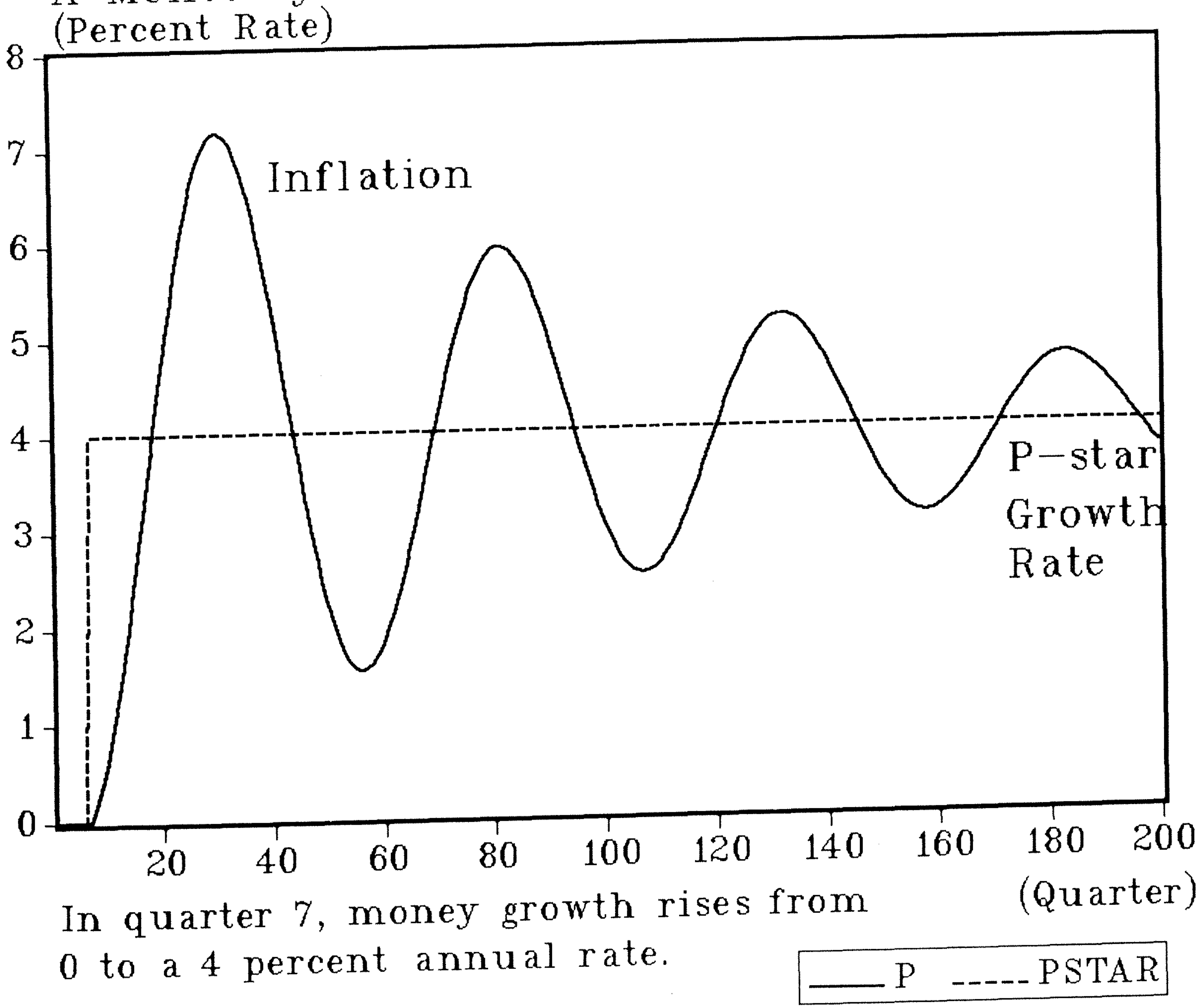
Inflation is measured from four quarters earlier.

Figure 3
Inflation and the M1 Price Gap



Inflation is measured from four quarters earlier

Figure 4
A Monetary-Induced Rise in Inflation



In quarter 7, money growth rises from 0 to a 4 percent annual rate.